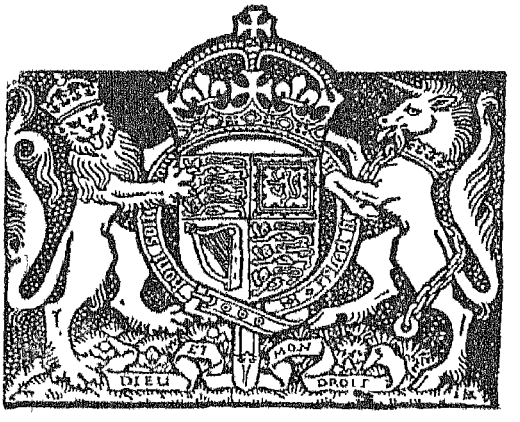

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STUDIES IN *PASPALUM SCROBICULATUM*, L. THE KODO MILLET

By G. N. RANGASWAMI AYYANGAR B.A., I. A. S.,
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The Kodo millet, *Varagu* (Tamil) and *Arika* (Telugu), occupies an area of well over a million acres in the Madras Presidency. The grain of this millet is easily preserved and proves a good famine reserve. It is a poor man's food. The crop is very drought-resistant. Only well-matured grains should be husked and used as food. Husks and immature grains are poisonous. This millet is considered safer for use as the grains get old. Both as food and fodder the crop is poor. While the crop is ripening it is considered dangerous to graze animals on it. This millet is grown mostly rain-fed, though in small areas under irrigation also. Trichinopoly and South Arcot districts have over 170,000 acres each; Kurnool, Nellore and Ramnad have each over 90,000 acres. The Nilgiris, Malabar and South Kanara are the only districts in which this crop is not grown. About 21,000 acres are raised under irrigation. Of these Coimbatore, Ramnad, Madura and Kurnool have about 13 thousand acres. This millet yields on an average 800 lb. of grain per acre with a range of 400 to 1200 lb. according to the tract. The yield of straw is about 1000 to 2000 lb. per acre. The straw is used as a manure in alkaline lands. This millet has been under study at the Millets Breeding Station and the following summarise the knowledge so far gained.

Seedlings. The seeds of this millet have a thick husk which is about 40 per cent. of the seed by weight. It is, therefore, slow in germination. On the fifth day after sowing are seen the first signs of sprouting. A single long leaf is visible and no stem is in evidence. All leaf-sheaths and under-surfaces of leaves are densely hairy. The mesocotyl is smooth with no rootlets and dries up soon. It is capable of elongation adjusting to varying depths of sowing. It is unpigmented though the adult plant develops purple pigment. When the seedlings are a fortnight old, the first secondary root makes its appearance. Secondary roots are also unpigmented.

Adult Plants. These are usually erect, and occasionally spreading or prostrate in habit and are 1 to 2½ feet in height. They differ in their leafiness. In a good leafy plant the leaves are broad and numerous and give it a dense, bushy appearance. Less leafy plants have narrow leaves giving them an all-stem and little-leaf look. The nodes are swollen or not according to varieties. The first node is hairy and the other nodes are glabrous. In a few varieties villous upper

nodes are met with. The internodes are solid. The length of internodes increases gradually from bottom to top in any tiller. The internodes, in most cases, are fully ensheathed. The number of tillers in varieties varies from 5 to 18. The early tillers set well. The later ones are more sterile. Nodes touching the ground strike root. They ascend from a prostrate and rooting many-noded base; simple or sparingly branched, usually five-noded. The leaf blades are linear to lanceolate-linear; equally wide or slightly constricted at base; glabrous; margins scabrid; smooth on either surface, broad or narrow; erect, arched or bent. The arched condition is associated with the broad leaf which droops and gives the plant its characteristic appearance. Narrow-leaved plants have very few bent leaves. The leaf is usually of a dark green colour. A few varieties have light green leaves. The midrib of the leaf is white or dull green in colour. The ligule is membraneous, colourless, broad or narrow. The junction of the leaf blade and sheath is usually covered with a felt of long hairs. Rarely such hairs are short. The leaf tip remains green in most varieties but in some it dries up to brown even before the heads ripen. The size of leaf varies with the varieties and a considerable range in their length has been noted resulting in differential habits.

Purple Pigmentation. This manifests in seedlings as a purple wash. With the growth of the seedling and the elongation of the leaf-blade, leaves begin to bend and from the bend to the tip there is a wash of purple. At a further stage of growth when the basal nodes show out, their nodal bands take on the pigmentation. With increased growth, such bits of internode as the intense ensheathing leaves bare, begin to have a wash of purple more of self colour and less of lines. Leaf junctions, axils and leaf margins are purple coloured. In some the tips of glumes develop purple. The stigmas show grades of purple ranging from dark to very faint purple. In the anthers purple rings and dots are developed on a yellow background. Anthers without any easily noticeable purple pigment occur occasionally. The stigmas and anthers dry to a brown colour of grades which parallel the depth of purple in them. After the flowering is over, the panicle branches get liberated from the sheaths and the peduncles also get coloured purple. The optimum manifestation of the purple pigment is from the flowering to the milky stage of the grain, after which there is a falling off. Advancing age, however, loosens out the internodes from the clasp of the sheaths and these together with prominent nodal bands retain the purple pigment as long as they continue to be sappy. Looked at *en masse* this field crop has a characteristic violet look. Though all the varieties are purple pigmented, the depth of colour varies. In some the colour is so much reduced that only a very careful examination reveals the pigment in odd parts.

Panicle—Emergence. The panicle arises usually from the node. The first sign of the growing panicle is a slight bulge

leaf-sheaths. The swelling increases gradually and the panicle is seen through the sheath slit. It takes about a week for it to emerge. When fully emerged it is enclosed by three overlapping leaf sheaths, which inroll one inside another at the tops. The flag and the leaf below it, likewise inroll at the top and, in most cases, do not separate even when the panicle is in full flower. In the inrolled region mentioned above the ends of the inflorescence remain stuck up. The upper end thus fixed, the floral branches, as they elongate, bend outwards at the centre. The enclosing leaf-sheaths are forced apart by the rapid growth and consequent arching of the panicle until thereby the tips are also forced out. This is the general rule but in a variety imported from Sierra Leone, the peduncles clear out of the leaf-sheaths, elongate and hold the panicles aloft and away from the leaf-sheaths.

Panicle—Arrangement. Excepting the lower three nodes, the other two bear panicles. From each of the two upper nodes three separate peduncles arise. Of these the central one aborts and the two lateral grow. The abortive one bears a sessile panicle. This panicle may contain one or two branches bearing rudimentary spikelets. Of the two free growing peduncles one grows quickly and shows out earlier than the other. The earlier is always bigger and has more spikelets and less of sterility. In the later peduncle the spikelets at the tips of the branches are usually sterile. Each of these peduncles gives rise to three branches one of which aborts, the other two showing a likewise differential growth and development. These branches repeat this trimerous process untill small spikelet-bearing branches of differential size arise and produce flowers. In this ultimate trimerousness some of the abortives get converted into long stalked single flowers. The weaker flower-bearing branches are mostly unbranched, whereas the stronger ones branch out and bear a larger number of flowers. The largest number of spikelets in a branch may be as many as 100.

Panicle—Branches. Each branch has a broad, flat rachis with a series of depressions corresponding to the situation of the spikelets. On the side on which the spikelets are situated, a central ridge runs along the entire length. On either side of the ridge the spikelets are arranged alternately in two series on short pedicels. In some varieties instead of the usual two-seriate condition, a branching of the pedicel gives rise to a non-seriateness, the spikelets being irregularly arranged. At the base of the branch it is two-seriate; in the middle the non-seriate condition prevails; and towards the tip the two-seriateness continues. The non-seriate condition is found in some cases along the entire length of the branch. Other variants to the simple branching of the pedicel and the production of two flowers are the following:— (1) *the pedicel instead of forking into two, branches into three,* each bearing a spikelet. (2) It may bear more than four flowers at different

levels. (3) Small branches arise at different levels on the ridge of the branch and these bear a fairly large number of flowers. In addition to the crowding induced by the branching of the pedicel, the double seededness of such non-seriate heads is the most important factor in the crowding and small size of the grain in the earheads that are not two-seriate. The disturbance of two-seriateness brings about a dense packing of spikelets on the flat rachis and contributes to the reduction in the size of the spikelets. Consequently the spikelets in these are ⅓ to ½ the size of those in the two-seriate panicles. It may be observed that the non-seriate varieties are early, lighter pigmented with grains of a lighter brown husk.

Spikelet—Single Seeded. The description of this spikelet has been elaborated from Hooker's Flora of British India in which a description of the variety with double seeded spikelets is not found. Spikelets orbicular, mostly decidedly plano-convex, falling entire from the short rudimentary pedicels and abaxial on the dilated rachis of spike-like racemes.

Glume I.	o (suppressed.)
Glume II.	More or less equal to the spikelet; convex; membranous; light green; deciduous; glabrous; 5-6 nerved.
Glume III.	Similar to Glume II, but less convex and more flat; light green; thin; glabrous; deciduous; 2-5 nerved; along the inner margins are seen shallow transverse pits whence the specific name "*scrobiculatum*."
Glume IV.	Horny; pale green; later develops a light or dark brown colour; glabrous; 5 transparent nerves; margin firm; obtuse; emucronate; persistent.
Palea.	Tightly embraced by the narrowly involute margins of Glume IV; similar in substance to Glume IV; 2 transparent nerves; the palea with flaps widened into a broad auricle below the middle; persistent.
Stamens.	Three; filaments short, 1 m. m. long, anthers-3, 2-3 m m. long; 2-loculed; locules open by longitudinal lateral sutures
Ovary.	Oval; translucent; stigmas-2, styles distinct and laterally exserted near the tip of the floret; styles feathery from one-third the length from the apex.
Lodicules.	Two; fleshy; serrated tips; broadly cuneate.
Grain.	Tightly enclosed by the slightly hardened glume and palea; rotundate—elliptic; very convex in front, flat on the back; pale; scutellum up to half the length of the grain.

Spikelet—Double Seeded. In the double-seeded spikelet, between Glume II and palea of Glume IV an extra flower is interpolated. It is enclosed in an extra glume and palea. This extra flower develops seed, each spikelet thus having two seeds. Abortive conditions of this double seededness freely occur interspersed with this double fertility and arise as follows. An extra flower is developed between Glume II and palea of Glume IV. It is a perfect flower and has only an extra palea. It does not set seed.

Opening of the Flower. The opening of the first flower is generally on the second day after the emergence of the panicle. This

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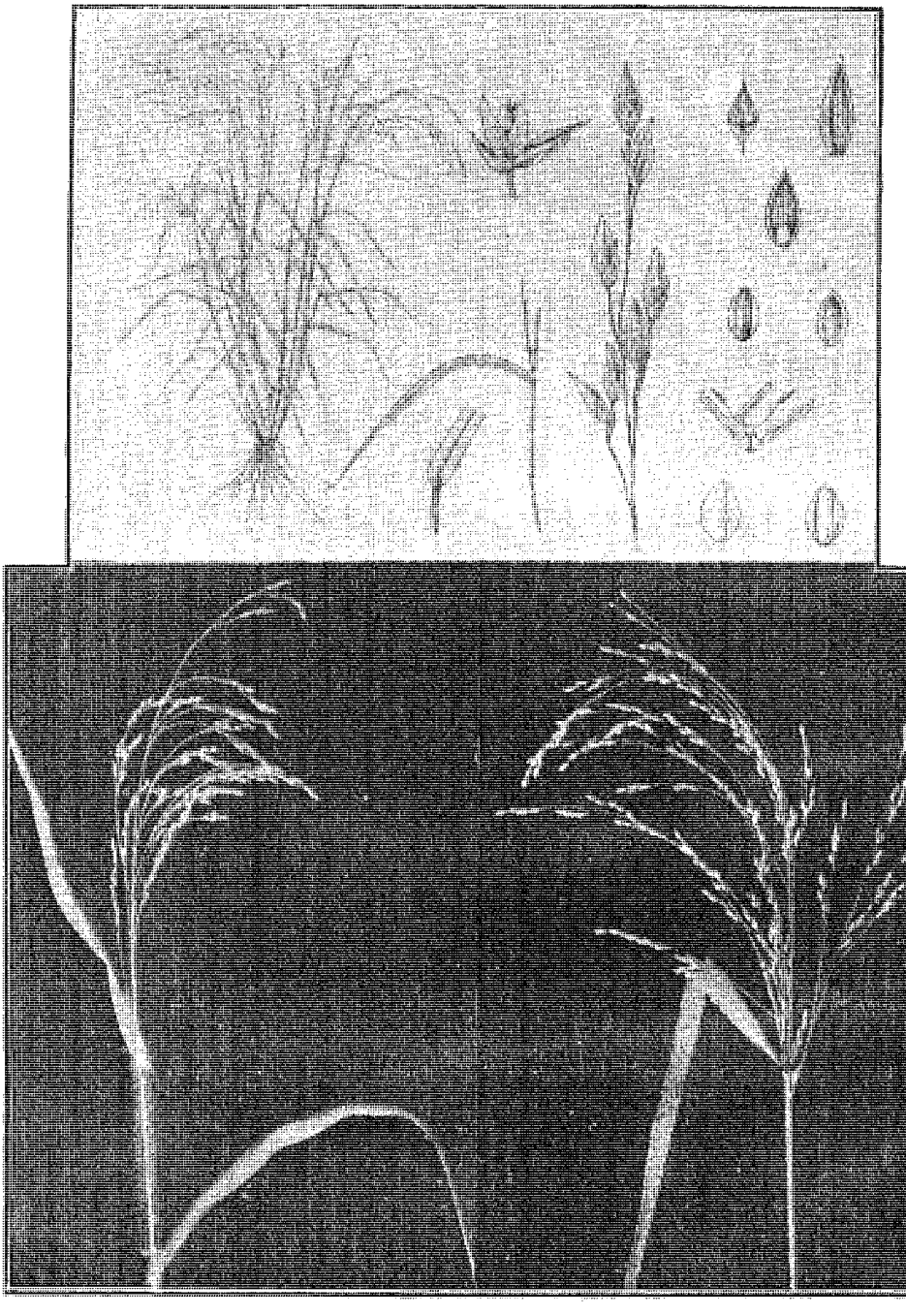
PALGHAT.

Panicum Miliaceum, L.



Densely Hairy. Hairless.

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Introduction. The botanical name of this millet *Panicum miliaceum* is derived from the old latin word *Milium* which means millet (Blatter 1935). In Russia this millet is known under the name proso. The common English names of this millet are Common Millet, Hog Millet and Broom Corn Millet. In India it has different names in different languages. In North India it goes under the names *Chehna, Chinwa, Bansi* and *Vari*. In South India *Variga* (Telugu) and *Panivaragu* (Tamil) are the most common names.

Origin and Distribution. This millet is widely distributed in the world It has been grown from very ancient times in India, Africa, Southern Europe, China and Japan. It is a recent introduction to North America. In India it is chiefly grown in the Punjab, the United and the Central Provinces, Bombay and Madras. The area that this millet occupies in the whole of India is not available. In the province of Madras its area could be computed to be in the neighbourhood of 500,000 acres. There are two zones in which the main areas of the crop are concentrated, namely the Guntur zone comprising Kistna, Guntur and Nellore districts with about 300,000 acres, and the Madura zone consisting of the districts of Madura, Ramnad and Tinnevelly, with an acreage of about 100,000. The rest of the acreage is distributed in small areas in the other districts of the presidency.

According to Komarov (1931) this millet is as ancient as wheat. Its origin is undoubtedly in the old world. Williams (1899) suggests an Egyptio – Arabian region as the home of this millet. Burkill (1935) states, "Vavilov (*Bull. Appl. Bot. and Plant-breeding*, 26, 1926, P. 180) calls attention to the way in which its rapid growth serves the nomads whose sojourn in one place is apt to be short, and he suggests that it was brought westwards from that great home of nomads, the centre of Asia, and has already obtained a large place in the agriculture of the Slavonic regions of eastern Europe in Roman times". Werth (1937) mentions, "after a consideration of the various theories of Vavilov, Schiemann, etc., it is concluded that the probable spread of this millet started from a broad girdle in North China, through Central Asia, South Russia into Middle Europe". Crozier (1894) is of opinion that this crop was introduced into the United States of America from the old world and Brandon (1932) believes that the Russian emigrants brought this over with them.

Uses. This millet is characterised by its short period of maturity which makes it very suitable as a catch crop. It has a very low water requirement (about two-fifths of what is required for wheat) and is able to evade drought by its quick maturity (Brandon, 1932). In the northern coastal districts of the Madras presidency it is raised as a dry land crop. It is sown in the late sowing season (October – November) and yields about 500 lb. of grain to the acre. In the southern parts of the presidency, it is raised in the cold (dewy) weather, invariably as an irrigated crop, when it yields close on 1000 lb. of grain per acre.

In the old world this millet is cultivated for its grain which is used as human food. In India it is husked, cooked and eaten like rice (Watt, 1901). In America it is used chiefly as a forage crop. Bailey (1922) mentions the following uses of this millet in America: "The seed is fed to stock and is used as a substitute for corn in areas where corn will not succeed and the sorghums will not mature. It is fed particularly to hogs. This practice gives it the name of hog millet. It is also an excellent poultry feed. Its protien content is almost as good as wheat."

Botanical Description. Hooker (1875) and Blatter (1935) have described this millet. In the following brief description we have freely drawn from them and have incorporated our special observations. *Panicum miliaceum*, L. belongs to the tribe *Panicae*, in the natural order Graminae. It is a herbaceous erect annual with a tendency to tiller freely, growing up to a height of 2—4 feet. It is leafy often up to the panicle and the leaves are linear and slender. The leaf sheaths enclose almost the whole internode. The ligule is short with a fringe of silky hairs. The leaf blade and sheath are very often covered with long hairs arising from conspicuous tubercles.

The panicles are slender, usually curved and nodding with long slender branches which are much divided even up to the fifth degree. The main axis is 6 to 10 inches long and from this 10 to 15 primary branches arise often singly, and sometimes in whorls of two or three along the length of the axis. The lower primary branches are longer and heavier than those higher up. The primary branches give off secondary branches. These again divide up further and further into ultimate thread-like branchlets each of which bearing two and very rarely three spikelets at the tip. The spikelets are about $\frac{1}{6}$" long and have 4 glumes which are glabrous, unequal, cuspidate and prominently nerved.

Glume I. is small and is about $\frac{2}{3}$ the size of Glume III.

» II. is almost as big as Glume III.

» III. is paleate neuter. Sometimes three stamens arise in this flower.

» IV. is broadly ovate, turgid and cartilegenous. The palea is of similar material. These enclose a full flower consisting of three stamens and one ovary with two plumose styles. There are two fleshy lodicules.

The kernel is firmly surrounded by the indurated shining glume and palea which are often coloured. The ripe grain easily sheds. The kernels form about 70 per cent by weight of the grain.

Anthesis and Pollination. With a view to effect successful hybridisation, pollination studies were made on this crop. They were on the field crop at Coimbatore which was in flower during the month of February 1937, *the regular growing season of the crop.*

From the appearance of the tip of the panicle at the collar of the flag, to its complete emergence from the flag sheath it takes about one week. The opening of the mature flowers does not wait for the complete emergence of the panicle. The flowers which are at the tips of the panicle start opening within 4 days from the appearance of the panicle. The flowering proceeds from top downwards. It takes about 10 days for the panicle to complete its flowering, though the bulk of the glumes open within the first week. Flowers open between the hours 10 a. m. to 12 noon, though stray flowers could be found to open till 1 p. m.

Coming to a typical individual flower, when mature, its fourth glume and palea slowly open out until they make an angle of about 50° between them. The anthers crowd in a column at the mouth of the slit and gradually slip out from between the glume and palea as they widen out. The stigmas whose long styles are bent and interlocked in the bud stage, release themselves and quickly droop out. The anthers dehisce longitudinally, about half a minute after their first appearance at the slit of the glume. This however varies with weather conditions. If the forenoon is very hot, the dehiscence is almost simultaneous with the appearance of the anthers. If the weather is cloudy, the dehiscence of the anthers is delayed by about a minute. In such weather, the flower opens later and the glumes keep open longer. A flower opens and closes in 5 to 7 minutes normally, depending however upon the weather conditions. The stigmas and anthers remain outside when the flower closes.

This millet is as a rule self-fertilised, though a very small amount of natural crossing does occur. The little interval between the opening of the flower and the dehiscence of the anthers makes this possible.

In this connection it will be interesting to note the experience of other workers in the pollination of this millet. Youngman and Roy (1923) studied the pollination of some lesser millets in the Central Provinces and were of opinion that they were mostly self-pollinated. Knuth (1909) mentions that stigmas and anthers protrude simultaneously and that the anthers approach the stigmas when the glumes close so that crossing is favoured at first and automatic self-pollination is possible later on. In Russia, Belov (1914) finds that pollen is shed within the flower before it actually opens and that self-fertilisation is invariable. He states that some natural crosses have also been met with by some workers on this millet. In Poland, Lewiki (1921) confirming the statements of Belov, notes that the opening of the flower

takes place from about 8 a. m. to 1 p. m. and was of opinion that the slight natural crossing that occurs is caused by insects and not by wind.

Artificial hybridisation. The very short interval between the opening of the flower and dehiscence of the anther makes artificial crossing a matter of very great difficulty. Emasculation has to be done well before there is any risk of taint from the readily available pollen. Youngman and Roy (1923) found that the slight pressure on mature flowers caused by passing the earhead through one's closed hand resulted in the opening of many mature flowers. At the Millets Breeding Station it was observed that on windy days a large mass of flowers opened simultaneously and earlier than usual. This earlier opening under pressure of hand was however found not to be early enough for safe emasculation. What was wanted was a little more time between the opening of the glumes and the dehiscence of the anther so that the emasculation could be done safely and without risk not only from the pollen from the same flower, but also from pollen available at the usual time of mass flowering. By examining the earhead, noting the mature flowers likely to open that day and passing such *individual flowers* gently between the thumb and fore-finger it was possible to induce them to open out earlier, by even an hour before their due time of opening. Flowers take about three minutes to open after the manipulation. The anthers in this case take a little longer time to dehisce and the emasculation is done quickly and safely. The desired pollen is also secured in a similar way. This method is essential for designing crossing work with parents whose F_1 characters cannot be depended upon to give a clue to successful crossing. But in the case of such known characters as purple pigmentation whose dominance over the green throughout is well known, it will be simpler to adopt the contact method of crossing described in detail elsewhere in connection with *Eleusine coracana* (Rangaswami Ayyangar, 1932). This method has been successfully used by Kadam (1935) in the case of this millet.

While at this subject of anthesis it may be recorded that odd instances have been met with in which the third glume which is usually neuter, has borne 3 stamens. These stamens were normal and they dehisced and shed their pollen after the anthesis of the bisexual flower. Another interesting floral abnormality is the presence of a fifth glume with a palea and a grain in between, producing two seeds in one spikelet. This was met with in a sample of seed from Russia (Belov, 1916). The glume and palea in this instance are absolutely like the fourth glume and its palea. The central axis is slightly prolonged and an extra grain borne. Such abnormalities occur mostly in the tip florets of the panicles. The manifestation of this doubleness is not constant in all the plants, nor earheads, nor in all the spikelets. Ten is the largest number of double grains observed in a single head. In a random sample of 50 heads only 21 showed double grains which ranged from one to 10. Most of the heads showed this doubling in one or two spikelets only. When double, the grains are small and not well

set. Beyond being an interesting curiosity there are no economic possibilities in this doubling.

INHERITANCE STUDIES

The study of the inheritance of the characters of this plant is in progress at the Millets Breeding Station. The mode of inheritance of the three characters—Purple Pigmentation, Hairiness, and Grain Colour is presented below.

Purple Pigmentation. As in all cereals, in this millet also there are types with and without purple pigmentation. This millet being slender and the manifestation of pigment sparse, the pigment is not prominent. A close examination has to be made of the various parts of the plant to determine accurately the distribution of the pigment. That the pigmented condition is a simple dominant to the green-throughout condition has been published. (Rangaswami Ayyangar, 1927, 1928 and 1934.) Kadam (1935) confirmed this observation. Since publishing the above, many types of this millet have been under observation. In addition to the green throughout type, two purple pigmented types have been met with, viz., (1) *Purple* type—young plants occasionally purple on lower leaf sheaths, glume tips purple, stigmas purple, and (2) *Light Purple* type—purple seen only at reproductive stage and that under a lens, glume tip very light purple, stigma purple tinged. The commonest South Indian types are the *Purple* ones. Types that are green-throughout are poorly represented. The *Light Purple* type is only met with in varieties from China and Russia.

As in the case of *Ragi* (*Eleusine coracana*) (Rangaswami Ayyangar and Krishna Rao, 1931) a factor **(P)** produces the basic purple pigment of the type met with in the Light Purple group. The addition of an intensification factor **(I)** results in the ordinary Purple whose genetic constitution is thus **PPII**, the constitution of the Light Purple being **(PPii)**. Plants that are Green-throughout may be allelomorphic to either of these purple pigmented types. The presence of purple is a simple dominant to its absence resulting in a plant that is Green-throughout. The presence of the intensification factor **(I)** is a simple dominant to its absence, **(i)**. The **(I)** factor can manifest itself only in the presence of **(P)**. This factorial interpretation explains the 9 : 3 : 4 ratio of Purple, Light Purple and Green-throughout met with in crosses designed to throw light on the inheritance of these factors. The data from the cross is presented in the following table. (Table I). In the tables the abbreviation P. V. stands for *Panivaragu*, the Tamil name of this millet.

Hairiness. Hairiness is a characteristic of this millet. This has been noted in all the descriptions of this plant by various systematic botanists. It is however not known that there are various grades of hairiness in these plants including some which border on hairlessness.

From the examination of the pure lines collected and grown at the Millets Breeding Station for some years, varieties could be classified into four groups according to their hairiness :

(1) The *densely hairy* type. This is the most hairy type. Hairs are densely distributed on both the surfaces of the leaf, on the leaf sheath, stem, node and panicle branches. The hairs are about 5 mm. long, and are best seen on the leaf sheath. There are, on the average 400 hairs per square cm. on the surface of the leaf sheath and the same number is found on the upper surface of the leaves. Pure line P. V. 14 is typical of this.

TABLE I. Inheritance of Purple Pigmentation.

CROSS XIX.

Generation	P. V. No	Pigment Groups		
		Purple.	Light Purple.	Green-throughout.
Parents	P. V. 91			Female
	„ 199		Male	
F_1		F_1		
F_2	„ 220	104	33	44
Expectation 9 : 3 : 4		102	34	45
				P = ·9
	F_3 (from P. V. 220.)			
Family No.	*Character of Selection.*			
P. V. 269	Purple	168		
„ 259	„	57	18	
„ 261	„	25	8	
„ 264	„	51	16	
„ 265	„	36	11	
„ 260	„	38		10
„ 263	„	61		20
„ 266	„	26		9
„ 262	„	129	41	53
„ 267	„	27	8	12
„ 268	„	79	27	38
„ 270	„	97	31	44
„ 272	Light Purple.		85	
„ 274	„		92	
„ 275	„		73	
„ 271	„		86	28
„ 273	„		69	21
„ 276	„		91	29

(2) The *hairy* type. This is slightly less hairy than P. V. 14. The hair length is about 3 mm. As in P. V. 14, the hairs are present in all the plant parts, but not so densely. On the leaf sheath there are about 280 hairs per square centimetre of surface. As a pure line this is separable from P. V. 14. This group is represented by the pure lines P. V. 31 and P. V. 97.

(3) The *sparsely hairy* type. This type of hairiness is less hairy than P. V. 31 and is separable from it in pure lines. The hairs are only about 2 mm. long and are sparse even on the leaf sheaths. On an average there are 120 hairs per square centimetre. The leaves and panicle branches appear to be practically free from hairs. Pure line P. V. 36 belongs to this group.

(4) The *hairless* type. This type is devoid of hairs on the leaf, the upper leaf sheath, stem and panicle branches. This is however not absolutely hairless. The lower leaf sheaths and nodes are slightly scabrous. This type is very distinct from the above three types, and is easily distinguished from them. This is represented by P. V. 96.

P. V. 96 is an introduction from South Africa and is the only one of its kind in the collection of pure lines. Though it is a hairless type it is without any economic disability. In yield it is as good as any local economic selection. This is very unusual inasmuch as foreign introductions of this millet have not fared well at Coimbatore. The South African varieties have however been an exception. It is interesting to note that the varieties from the *Northern Circars* and the *Deccan* districts of this presidency are the most hairy and belong to group 1. Those from the central and southern districts are less hairy and belong mostly to groups 2 and 3. In the *Circars*, this millet is cultivated as a rainfed crop, while in the south it is invariably an irrigated crop.

The genetic relationship of these hair groups is interesting. Investigations in the inheritance of this hairiness pursued at Coimbatore show that the *hairless* condition is always recessive to the hairy condition. The *densely* hairy condition is brought about by the presence of three factors whose cumulative effect results in a dense manifestation of hairs on the plant. In crosses between the hairy and hairless types, the F_1 generation plants are less hairy than the hairy parent, but the heterozygous dominants in the F_2 are not easy of separation. This interference with the expression of hairiness in the heterozygous condition results in acute difficulty in the classification into sub-groups of hairiness, in the dominant hairy group. A cross between P. V. 96 (*hairless*) and P. V. 36 (*sparsely hairy*) resulted in a *sparsely hairy* F_1 and segregated into 486 *sparsely hairy* plants and 159 *hairless* plants in the F_2 (P = ·9). Eight selections were carried forward to a third generation. Of these the four *hairless* selections bred true to hairlessness. Of the four hairy selections, two were true to the *sparsely hairy* character and two segregated again like the F_2 confirming the monogenic difference between the parents.

The second cross was between P. V. 96, the *hairless* parent used in the previous cross and P. V. 97, the *hairy* type. The F_1 was less hairy than the hairy parent and the F_2 gave a 15 : 1 ratio of *hairy* to *hairless* plants; the actual numbers being 281 and 23 (P = ·4). The hairy group was inseparable into *hairy* and *sparsely hairy* sub-groups as the one ran into the other. It may be noted that P. V. 97 is from Russia. The plants of the F_2 were short and stunted in growth. The same *hairless* parent P. V. 96 was therefore crossed with P. V. 31, a local variety of the same hairy type as P. V. 97. The F_1 was similar to the last one and the F_2 segregated in a 15 : 1 ratio of *hairy* and *hairless* plants, the actual numbers being 564 and 25 respectively (P = ·04). From this 35 selections were carried forward, 28 *hairy* and 7 *hairless*. In the F_3, the 7 *hairless* bred pure. Of the 28 *hairy* selections, 15 were pure and were of various indistinguishable grades of hairiness and 13 selections threw *hairless* plants. Out of these 13 segregating families, eight were of the 15 : 1 type (558 *hairy* and 39 *hairless*, P = ·7) and five of the 3 : 1 ratio (139 *hairy* and 43 *hairless*, P = ·7). This behaviour shows that the presence of a second factor for hairiness increases the amount of hairiness and brings it up to the *hairy* standard.

The third cross was again between the same *hairless* parent, P. V. 96 and the *densely hairy* type, P. V. 14. The F_1 was as expected, less hairy than the *densely hairy* parent. The F_2 segregated in a 63 : 1 ratio of hairy and *hairless* plants (335 hairy and 7 *hairless*, P = 5). The hairy plants in the F_2 were of various grades of hairiness ranging from the *densely hairy* to the *sparsely hairy* condition so that it was impracticable to separate them into definite sub-groups, the heterozygous blends adding to the difficulty. The *densely hairy* type, P. V. 14 is a local variety, typical of the cold weather rainfed types common in the Guntur district. The hairiness in this type seems thus to be the effect of the addition of a third factor for hairiness.

From the above data it has to be inferred that hairiness is governed by the operation of at least three independent factors, any one of which produces hairiness and that the *hairless* type is the result of the absence of all these three factors. These factors are comulative in their effect, the intensity of the hairiness increasing with the addition of the factors. These three factors for hairiness have been designated $\mathbf{H_1}$, $\mathbf{H_2}$, and $\mathbf{H_3}$.

Grain Colours. The kernel of this millet is enclosed within the fourth glume and its palea. These two floral parts are indurated and shining. They are of various colours and this colour of the grain is the commonest varietal diagnostic character. The various types of grain colour met with so far and their inter-relationship and inheritance are described below.

Grain colours in *Panicum miliaceum*. The Common Millet.

		Colour of glume	Colour of palea.
(1) Dark Olive Grey	...	Dark Olive Grey	Dark Olive Grey
(2) Buff Yellow	...	Buff Yellow	Buff Yellow
(3) Light Olive Grey	...	Light Olive Grey wash	Dark Olive Grey
(4) Light Buff Yellow	...	Light Buff Yellow wash	Buff Yellow
(5) Ivory Grey	...	Ivory Yellow	Light Olive at base
(6) Ivory Yellow	...	Ivory Yellow	Light Yellow at base

Of these six colours Nos. 1 and 2, Dark Olive Grey and Buff Yellow are the colours met with in the Madras varieties. In varieties from Russia, South Africa and China, all the six colours are present. Except P. V. 96 (Ivory Yellow) the other types of grain colours have not taken kindly to their new surroundings at Coimbatore.

The starting point in this grain colour scheme for these six colours is Buff Yellow, which colour operates in wholeness on both the glume and the palea. The addition of the factor **O** to this basic colour **Y** results in the Dark Olive Grey colour of grain. The factor **O** is a simple dominant to **o**. Crosses between these two colours have given simple 3 : 1 segregations, the total figures obtained being 328 Dark Olive Grey and 101 Buff Yellow (P = ·5).

The other four grain colours represent stages in the reduction of the expression of whole colour on the glume and palea. Light Olive Grey and Light Buff Yellow represent the first stage. Here the colour of the glume gets

diluted to a mere wash, the palea practically retaining its full colour. This dilution of the colour of the glume is brought about by a factor **L**. The operation of this **L** factor along with the factor **O** is presented in the following table.

TABLE II. The Interaction of the Factors O and L

CROSS XXV.

Generation.	P. V. No.	Grain Colours			
		Light Olive Grey.	Dark Olive Grey.	Light Buff Yellow.	Buff Yellow
Parents	P. V. 36				Female
	„ 201	Male			
F_1		F_1			
F_2	„ 222	83	29	27	10
	Expected 9 : 3 : 3 : 1	84	27·9	27·9	9·3
					P = 9
	F_3 (from P. V. 222 family).				
Family No.	*Character of Selection.*				
P. V. 294	Light Olive Grey	132			
„ 299	„	68			
„ 291	„	69	24		
„ 295	„	51	17		
„ 290	„	94		29	
„ 297	„	80		28	
„ 300	„	42		13	
„ 292	„	61	21	22	8
„ 293	„	104	32	36	10
„ 296	„	88	30	33	9
„ 298	„	33	12	13	5
„ 301	„	18	5	6	1
„ 303	Dark Olive Grey.		82		
„ 305	„		79		
„ 302	„		64		20
„ 304	„		98		31
„ 309	Light Buff Yellow.			64	
„ 306	„			37	11
„ 307	„			29	9
„ 308	„			69	24
„ 310	Buff Yellow.				86

From the above data it will be seen that a factor **L** dilutes the colour on the glume and that it is independent of the **O** factor in inheritance. The interaction of these two factors **O** and **L** results in the production of the four grain colours:— Dark Olive Grey, Buff Yellow, Light Olive Grey and Light Buff Yellow.

A second factor designated **I** inhibits the expression of colour on the glume making the glume Ivory Yellow. The effect of this inhibition is also felt on the palea. The colour of the palea is reduced and is confined to its base. This inhibition factor has also proved a simple dominant to whole colour. The interaction of the **I** and **O** factors is presented in the following table. (Table III).

From this table it will be seen that the inhibitory factor **I** operating independently of the **O** factor gives rise to the colours Dark Olive Grey, Buff Yellow, Ivory Yellow and Ivory Grey.

TABLE III. The Interaction of the factors I and O.

CROSS VII.

Generation	P. V. No.	Grain Colours			
		Ivory Grey	Dark Olive Grey	Ivory Yellow	Buff Yellow
Parents	P. V. 96			Female	
	,, 31		Male		
F_1		F_1			
F_2	P. V. 129	337	94	117	41
	Expected 9 : 3 : 3 : 1	331·4	110·4	110·4	36·8
				P = ·3	
	F_3 P. V. 129 family				
Family No.	*Character of Selection.*				
P. V. 157	Ivory Grey	95			
,, 168	,,	15			
,, 167	,,	10	3		
,, 175	,,	22	7		
,, 176	,,	5	2		
,, 158	,,	83		26	
,, 159	,,	69		27	
,, 160	,,	34		10	
,, 170	,,	65		19	
,, 161	,,	53	17	14	9
,, 162	,,	34	12	10	3
,, 164	,,	16	5	5	4
,, 169	,,	33	11	12	4
,, 172	,,	44	20	14	6
,, 186	Dark Olive Grey		92		
,, 187	,,		69		
,, 189	,,		121		
,, 163	,,		17		9
,, 171	,,		34		8
,, 185	,,		59		20
,, 188	,,		47		16
,, 190	,,		46		11
,, 182	Ivory Yellow			87	
,, 183	,,			26	
,, 177	,,			3	2
,, 179	,,			6	1
,, 180	,,			23	10
,, 181	,,			20	7
,, 184	,,			26	9
,, 191	Buff Yellow				56
,, 192	,,				64
,, 193	,,				56
,, 194	,,				58
,, 195	,,				82
,, 196	,,				81

Reddish Orange Coloured grain. This third whole-colour is a new one that was met with in the Russian and Chinese collection. The crop raised from this seed did not grow well and seems unsuited to Coimbatore conditions. This type was crossed with Buff Yellow, the starting point in the grain colour scheme presented above. The results of this cross are presented in the following table.

TABLE IV. Grain Colours Buff Yellow and Reddish Orange.

CROSS V.

Generation	P. V. No.	Grain Colours	
		Buff Yellow	Reddish Orange
Parents	P. V. 36	Female	
	,, 97		Male
F_1		F_1	
F_2	,, 128	289	106
	Expected on 3 : 1 basis	295	99 P = ·4
F_3 (from P. V. 128 family)	Character of		
Family No.	*Selection*		
P. V. 147	Buff Yellow	123	
,, 149	,,	136	
,, 156	,,	104	
,, 148	,,	84	31
,, 150	,,	62	18
,, 151	,,	111	33
,, 152	,,	79	26
,, 155	,,	84	24
,, 153	Reddish Orange		114
,, 154	,,		132

From the above table it will be seen that the grain colour Reddish Orange is a simple recessive to Buff Yellow. A factor $\mathbf{B_f}$ suppresses the red in this Reddish Orange and leaves the grain Buff Yellow in colour. Reddish Orange grains have the genetic constitution $\mathbf{YYb_fb_f}$, the Buff Yellow grains being $\mathbf{YYB_fB_f}$.

SUMMARY

The names, origin and distribution of the common millet *Panicum miliaceum*, Linn. are given in detail with a full botanical description of the plant. A review of the experiences in the anthesis and pollination of this millet is given together with a record of the observations at Coimbatore. For successful hydridisation it is found necessary to have a safe interval between the emergence of the anther and its dehiscence. It has been possible to secure this interval by proper manipulation of individual mature flowers, one hour before the usual opening time. Rare instances have been noted of the third glume bearing anthers and of the existence of poorly formed double grains, the doubling being brought about by the addition of an extra pair of fertile glume and palea.

There are two types of Purple Pigmentation in the plant, the Purple and the Light Purple. In the absence of the **P** factor for purple pigmentation the plants are Green Throughout (**pp**). **P** is a simple dominant to **p**. An intensificatton factor **I** makes the difference between the Purple and Light Purple types. Purple (**PPII**) is a simple dominant to Light Purple (**PPii**). A 9 : 3 : 4 ratio is obtained between Purple, Light Purple and Green Throughout.

The characteristic hairiness in the common varieties of this millet is governed by the operation of at least three independent factors any one of which produces hairiness. The hairless type is the result of the absence

of all the three factors for hairiness, namely H_1 H_2, and H_3. These factors are cumulative in their effect, the intensity of the hairiness increasing with the addition of each **H** factor. The *densely hairy* type is H_1, H_2 and H_3.

The common grain colours in the Madras varieties are Dark Olive Grey and Buff Yellow. A simple dominant factor **O** makes Buff Yellow into Dark Olive Grey. A second factor **L** lightens these two grain colours and produces the colours Light Olive Grey and Light Buff Yellow. Factor **L** which lightens the colour on the glume is a simple dominant to its absence. A third factor **I** inhibits the expression of colour on the glume making it Ivory in colour. It affects the palea also and restricts the colour to its base. Factor **I** is a simple dominant to its absence. The two grain colours Ivory Grey and Ivory Yellow are the result of the operation of this **I** factor. Reddish Orange, a third whole colour, is a simple recessive to Buff Yellow. A simple dominant factor B_f suppresses the Red in the Reddish Orange producing the Buff Yellow.

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Studies in the Barnyard Millet—*Echinochloa colona* var. *frumentacea*, C. E. C. Fischer.

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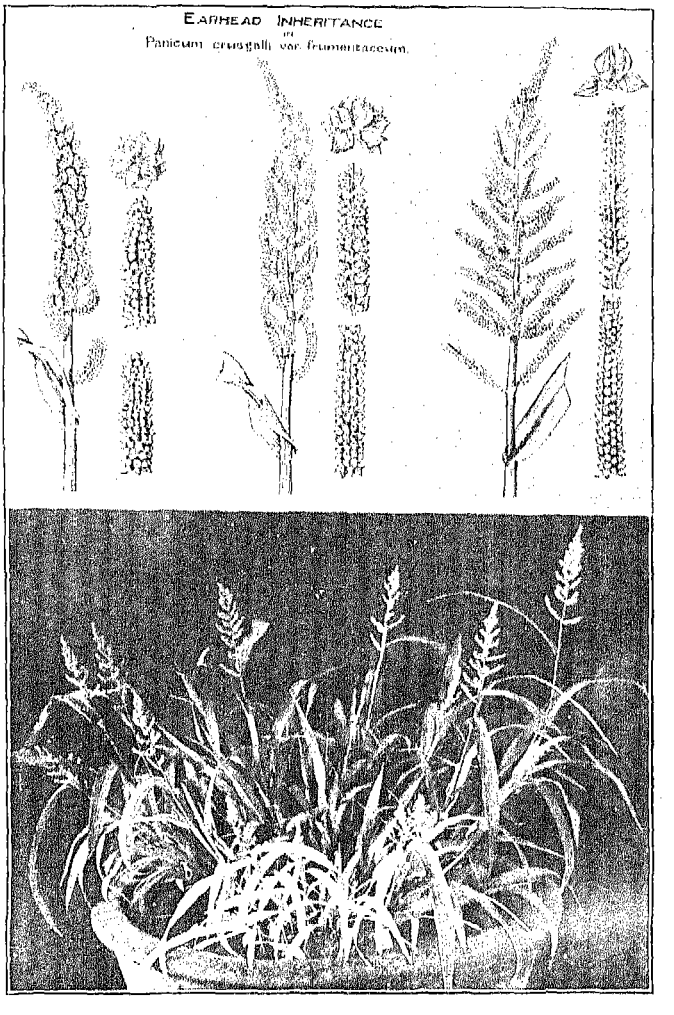

Fig. 1. (Top) Inheritance in ear-head shape. (Left) Compact head; (Right) Open head; (Middle) F_1; Single branches:—Top—cross section; Middle—rear and bottom—front view.

Fig. 2. (Bottom) Striped plant.

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The Barnyard millet, known in Tamil as *Kuthiraivali* (=horse-tail), is one of the less important millets of the Madras Presidency. Except in certain restricted tracts its importance as a food crop in India is not much. In view of the fact that it forms a good famine crop and also comes to the rescue of very poor cultivators, some of its characters were studied at the Millets Breeding Station and are presented below:—

This plant is considered to have been first brought into cultivation in India That it has been grown all over India since very remote times is seen by the fact that it has a name in Sanskrit, as well as in every one of the other Indian languages.

Werth (1937) mentions this plant occurring as a weed of cultivation in the temperate and tropical zones of both hemispheres, particularly the Northern and that it is cultivated as a millet (as a poor man's millet) in India, China, Japan, Dutch India and in smaller quantities in Africa. In China and Japan particularly it is said to be used as a substitute crop when paddy fails.

Its composition is given by Church (1886) as follows:—

		In 100 parts.
Water	...	12·0
Albuminoids	...	8·4
Starch	...	72·5
Oil	...	3·0
Fibre	...	2·2
Ash	...	1·9

The nutrient ratio here is 1 : 9·5 and the nutrient value is 88.

This millet is used in India either boiled in water like rice, or parched or boiled with milk and sugar.

As a fodder it seems to have attracted greater attention especially in the U S. A. Bressman and Fry (1932) consider this plant as the best late season feed, taking the place of maize in certain parts, which are unsuitable for maize. Thatcher (1900) gives the following composition of this plant as a forage crop.

Composition of feeding stuff at different stages of growth.

Feeding stuffs	Water	Protein	Albuminoids	Ether extracts	Nitrogen free extracts	Crude fibre	Ash
Millet: Heads just appearing	10·24	8·41	5·79	2·54	32·03	35·86	10·92
Headed out seeds near ripe.	10·47	6·12	4·49	1·52	43·33	29·10	9·41

He concludes that here the protein decreases rapidly while heading out and to obtain a fodder having as narrow a ratio of flesh-forming to fat-forming foods as possible the crop should be cut at as early a stage as it can be well cured. As a roughage it can be allowed to grow till seeds are formed.

Lindsey (1900) gives the following coefficients of digestibility of this plant: green, as hay and as silage with soybean, obtained with sheep.

Coefficients of digestibility of millet, millet hay etc.

	Dry matter	Protein	Fat	Nirogen free extracts	Crude fibre	Ash.
	%	%	%	%	%	%
Green millet, early to late bloom	71	69	63	72	73	64
Millet hay, full bloom	56·5	47·5	48	53.5	62	43·5
Millet and Soy bean silage	59	57	72	59	69	—
Corn and soy bean silage	69	65	82	75	65	—

He points out that when harvested early, in blossom, the fodder contains less nitrogen-free extract matter, more fibre or woody matter and rather more ash than corn fodder and so it must be cut when in blossom, to secure it in the most desirable condition for feeding.

On well-manured soils it gave 11,297 lbs. of straw and 66·7 bu. per acre and 12—15 tons per acre of green forage. Wood (1928) gives the yield of straw as 2,000 lbs. per acre, Mukerji (1915) records 800 lbs. and Mollison (1901) 1,500 lb. Watt (1889) states that the straw is used much in the Madras Presidency and Mysore as cattle fodder, though considered inferior to ragi as well as to paddy straw.

Kuthiravali is sown mostly as a rainfed crop. In the drier districts, it is grown as a subordinate crop to sorghum (Duthie and Fuller 1882) or maize (Watt l. c.) The plant can be grown either on light sandy soils (Duthie and Fuller. l. c.; Mollison. l. c.) with fair rainfall or in water-logged areas (Wood. l. c ; Watt. l. c.), such as lowlands or banks of rivers that often get submerged. Mukerji (l. c.) reports that rough jungle land could be used. It withstands transplanting (Mollion l. c.) The crop requires little or no manuring.

The seed rate is generally 8—10 lbs. per acre and when sown with a drill about 6—8 lbs. per acre. Wood (l. c.) quotes 35 lbs. per acre. The July sown crop is harvested in October

In Punjab this plant is said to be ploughed into the soil as a green manure.

Systematics. Hooker (1897) brings this plant under the sub-section *Echinochloa* of the genus *Panicum*. He recognises two very closely allied species viz. *Panicum crusgalli*, Linn. and *Panicum colonum*, Linn. The cultivated species is regarded as a variety of *P. crusgalli*. In his species of *P. crusgalli*, Linn. he finds innumerable forms so that it became "impossible to find characters constant enough for their limitation". He finds that *P. colonum* Linn. exhibits a gradual transition into *P. crusgalli* and *vice versa*. The cultivated variety *furmentaceum* has been assigned to both. Cosson and Thwaites are reported having regarded *colonum* as a form of *crusgalli*.

Cook (1908) mentions that the *Panicum crusgalli* of Linnaeus does not occur in the Bombay Presidency. He considers the cultivated form as a variety of *P. stagnium*, Retz.—*P. stagnium*, Retz., var. *frumentacea*, Trinn. The species *crusgalli* has no ligule. *P. frumentaceum*, Roxb. and *Oplismenus frumentaceus* Dalz. and Gibs. are given as synonyms of *P. stagninum* var. *frumentacea*. He remarks that *P. colonum* is very similar to var. *frumentaceum*, Roxb. but a more slender plant with smaller spikelets.

Chevalier (1922) quotes the following synonyms for this plant: *P. frumentaceum* Roseb., *P. grossum*, L. *P. segetale*, Roxb., *Echinochloa frumentacea*, Link., *Oplismenus frumentaceus*, Kunth. *P. frumentaceum* is said to be a variety of *P. crusgalli*, L. It is considered by most authors that *P. frumentaceum* possesses characters intermediate between those of *P. crusgalli*, L. and *P. colonum*, L.

Bressman and Fry (1932) distinguish the weed *crusgalli* from the cultivated millet by its greater hairiness of the glumes, and the longish seeds. The millet is less hairy and has broader seeds.

Fischer in Gamble (1934) removes the group from *Panicum* and gives the plants a separate generic stand, viz., *Echinochloa*. Under this genus he ennumerates 3 species:—

1. *Echinochloa colona*, Link. = *P. colonum*, L.
2. *Echinochloa crusgalli*, Beauv. = *P. crusgalli*, L.
3. *Echinochloa stagnina*, Beauv. = *P. crusgalli*, L.

The cultivated species is treated as a variety of *colonum* viz. *E. colona* var. *frumentacea*, C. E. C. Fischer = *P. crusgalli*, Linn. var. *frumentaceum*, Hook.

The following is the description of the species as given by Gamble:—

Echinochloa, Beauv. **Annual or perennial, often tall herbs. Leaves narrow. Inflorescence of crowded panicles of loosely arranged, secund, spiciform branches bearing spikelets from the base or near it; rachis triquetrous. Spikelets ovate**

to elliptic or lanceolate—oblong, 2-nate or clustered, articulated on and falling entire from the pedicels.

Glumes membranous, unequal; the lower much the shorter, mucronate, cuspidate or awned, the upper coincident in outline with the spikelet, acute, cuspidate or shortly awned. Lemmas: Dissimilar; the lower equalling the upper glume (excluding cusp or awn) its palea 2-keeled, empty or containing a male floret; the upper subcoriaceous or crustaceous, ovate, to elliptic-oblong, obtuse or apiculate, polished, very convex on the back, its pales as long, with rounded sides and flaps, containing a bi-sexual floret. Lodicules 2. Stamens 3. Styles free. Grain broadly elliptic, plano-convex.

Racemes simple, rather distant ·3–1·25 in. long; lower glumes and upper glumes about equal, obtuse or cuspidate. Annual, up to 2 ft. high; leaves 2-8 in long, ·1–·45 in. wide, ligule 0; spikelets ovoid ·1–·12 in. long; lower glume ·04–·05 in. long; upper ·09–·11 in. long; lemmas ·08–·1 in. long lower with male floret.....*colona*.

Racemes usually more or less branched ·8–2 in. long; lower glume and upper lemma cuspidate or awned, the latter the longer; lower lemma often awned:

Annual, up to 3 ft. high leaves 3–21 in. long; ·2–·5 in. wide, ligule 0, junction of blade and sheath glabrous, usually marked by a brown zone; spikelets ·15–·18 in. long; lower glume ·07–·12 in. long, upper ·15–·17 in. long; lower lemma empty, ·14—·17 in. long, upper ·12–·15 in. long; awn of lower lemma up to 2 in. long..... *crusgalli*.

Usually perennial, up to 6 ft. high; culms rooting and often branching from submerged nodes; leaves 3–18 in. long, ·2–·4 in. wide, ligule a fringe of stiff hairs, sometimes absent on the uppermost leaf; lower lemma empty or with a male floret. Otherwise as in the last species.....*stagnina*.

Echinochloa colona (link.) var. *frumentacea*, C. E. C. Fischer: a taller and more robust plant with dense, sometimes corymbose panicle, cultivated.

Observations on flower pollination. Hildebrand (in Knuth 1909) reports that only self-pollination is possible in this species, owing to the simultaneous protrusion of stigma and anthers, but crossing may be effected when the anthers have fallen, as the stigmas are persistant.

Youngman and Roy (1923) found the flowers opening between 7–30 and 8–30 a. m. They observed that the stigmas and anthers emerge simultaneously. The stigmas spread out immediately on emerging, while the anthers dehisce only after about 1—1½ minutes. The glumes are observed to close back after half an hour.

Observations made at the Millets Breeding Station, Coimbatore on two types of panicle shapes, viz., open and compact, gave the following results The plants were grown under irrigated conditions. The observations were done on three plants in each type. The plants commenced to flower in about two months after sowing. The tip of the leaf subtending the panicle (flag leaf) appears first and takes about 10 to 14 days for the complete emergence of the flag. The appearance of the panicle is almost simultaneous with that of the flag, but its emergence is gradual, taking from 9 to 13 days.

The flowers begin to open in the same order as they emerge out of the sheath. The first flowers open as soon as the panicle tip emerges out. The order of flowering is thus from the tip of the panicle to the base. But in the

individual spikes the spikelets along the two margins open earlier than those at the middle. The flowering period is 19—22 days in the open panicles and 2 or 3 days more in the *compact* ones. The largest number of flowers open during the sixth to eighth day from the commencement of flowering. The opening of the individual flowers is between 5-10 a. m. The maximum number of flowers open between 6 and 7 a. m.

The glumes open out very gradually and at the mouth of the gaping glumes the two stigmas and the anthers stand out like a column. Two to four minutes later the stigmas emerge out of the lemma in a column and spread out on either side. The stamens thus come to occupy the central position. The filaments begin to elongate gradually in about 1 to 8 minutes after the spreading of the stigmas. The dehiscence occurs only when the filaments have elongated to their maximum. The dehiscence is by lateral sutures. It begins at both ends and meets in the centre. The glumes close again in about 5 to 10 minutes after the dehiscence. The stamens and stigma remain outside the closed glumes. The whole process, from the opening of the glumes to their complete closing, takes about 24 minutes.

Inheritance of characters.

I. - *Anthocyanin pigmentation.* The only anthocyanin pigmentation met in this plant is purple. When the plants do not show any trace of the pigmentation they are designated as 'green through-out' (abb. GT.) The purple pigment normally manifests itself in the following regions of the plant:

(a) Vegetative parts—nodes, internodes, as two bands on the upper and lower sides of the nodes, leaf margins, midrib, sheath, panicle-rachis, glumes.

(b) Reproductive parts:— lemmas, anthers and stigma

Three grades of pigmentation designated P3, P2, P1, in descending order of their intensities, are met with. The anthers and stigmas show various colorations on drying corresponding to the grade of the plant-pigmentation. The following gives the chief differences between the various types:

Class of pigmentation.	Character and incidence of pigmentation				
	Vegetative Parts.	Reproductive parts			
		Anthers		Stigma	
		fresh	dry	fresh	dry
P.3	Deepest purple of all types	deep purple	deep blue	deep purple	black
P.2	Pigmentation less than in P_3	purple	a blue ring around the sutures	purple less than in P_3	dark brown
P.1	Pigmentation less than in P_2	yellowish brown	brown	light purple	brown
GT	No purple pigmentation, all green	yellow	brown	colourless	pale brown

A certain amount of fluctuation in the depth of pigmentation occurs in each of the three types. In the following segregations it was found that P.3 and P.2 groups were often rather difficult of separation and in certain cases the P.1 almost approached P.2.

(a) *Purple and green segregations:*—

Two kinds of segregations were met with, viz., a monofactorial and a bifactorial one.

The bifactorial segregations gave the following F_2 proportions.

Female parent = Green throughout
F_1 = P.2
F_2:—

	P.3	P.2	P.1	GT
Observed	266	80	88	44
Expected on 9:3:3:1	268·9	89·6	89·6	29·9

$X^2 = 7·73$ $P > ·05$

In the monofactorial segregations the following F_2 proportions were obtained:—

Female parent = green throughout.
F_1 = P. 1
F_2:—

	P. 2	P. 1	GT
Observed	29	71	33
Expected on 1:2:1	33·25	66·5	33·25

$X^2 = 0·84$ $P > 0·50$

The same proportions were met with in the further progeny of the hybrid. (Total of 9 families gave P. 2 = 330; P. 1 = 628; GT = 329. calculated P.2 = 321·75; P.1 = 643·5; GT = 321·75). This clearly indicates a 1:2:1 ratio. According to expectations all the P.1 selections proved to be heterozygous.

(b) In segregations between the three pigmentation groups, the 1:2:1 proportions were again met with:—

	P. 1	P. 2	P. 3
Total of 20 lots	751	1540	890

The P. 2 group is smaller and the P. 3 group larger than they should be for an exact 1:2:1 ratio, because their separation is not quite easy, the obvious P. 2 alone going into the middle group. Subsequent selections however showed that the P. 2 were all heterozygous and the P. 3 and P. 1 selections bred true.

It is evident from these that there are only two factors responsible for pigmentation in this plant. Further, it is evident that pigmentation differences between the heterozygotes and the pure ones are easier to be noted in the monofactorial segregations than in the two factor ones.

The factors may be designated as follows:—

$P_2P_2P_1P_1$	P. 3	$p_2p_2P_1P_1$	P. 1
$P_2P_2p_1p_1$	P. 2	$p_2p_2p_1p_1$	G. T

II. *The Panicle* (Plate I, Fig. 1). The panicle is conical in appearance. The number of panicles on a plant depends on its branching and tillering capacity. Each panicle is peduncled.

The peduncle is cylindrical and is continuous with the rachis, which however is angular. The spikes arise in whorls of 2 or more often 3—4, or sometimes 5. Each whorl thus constitutes more or less a node. The disposition of the whorls is more distant at the base and becomes less distinct and more congested towards the apex. The spikes arise on the face and not on the angle itself. They alternate in successive whorls so as to give a $\frac{1}{2}$ taxis. Thus the panicle shows a tetraquetrous arrangement. Consequent on the congestion towards the apex the whorls may become disturbed but still the tetraquetrous nature is kept up. The length of the spikes reduces gradually from the base towards the apex and the ultimate apex ends in a spike. This arrangement is responsible for the conical shape of the panicle.

The spikes are more or less ascending. The base of the rachis is somewhat pulvinate. The node at the base of the pulvinus is pubescent. Hairs, isolated or in tufts of 2—3 are found on the rachis, at the base of the spikelets. Groups of spikelets are arranged distichously along the dorsal side of the rachis. These groups consist of 3—4 spikelets distichously arranged on a short rachilla. The spikelets are all more or less equal in size. In general design they appear to be arranged in horizontal rows of 4 to 5 spikelets. The rachis attenuates towards the apex. The number of spikelet groups, however, remains the same and consequently the spikes tend to curve on their ventral side. This becomes more pronounced as the grains begin to mature. The spike ends may be seen almost spirally twisted and bent towards one side to avoid overlapping the upper one, so that the panicle gets a plaited appearance.

Two distinct types in head-shape could be distinguished, viz., Open and Compact.

In an open panicle the spikes are more or less horizontal and may or may not be curved towards the tip. The interval between the whorls is greater than in a compact panicle. The length of the spike is also greater and the spikelet groups are more spread out.

The compact panicle on the other hand shows the spikes much plaited. The spikes are much shorter and spikelets are very close together.

Further, the spikes in the 'opens' have a greater number of spikelet groups with usually 2—3, often 4, and rarely 5 spikelets per group. The 'compacts' on the other hand have usually only 3-4 spikelets per group, often 2 and very rarely 5.

An intermediate condition between the lax-ness of the 'opens' and the plaited appearance of the 'compacts' is met with. This is termed the 'semi-compact' head. In this the spikes do not completely overlap one another so that the main rachis becomes visible.

An analysis of typical heads gave the following results :—

Panicle type	Average number of spikelets	Average length of spike	Average number of spikelets per cm.
Open	26	2 8	9
Compact	22	1 9	12

Thus it becomes apparent that the headshapes are distinguished by the difference in the length of the spike and secondly the denseness of packing of the spikelets, i. e. the number of spikelets per cm. A similar experience is met with in the *E. coracana* also. (Ayyangar *et. al.* 1932).

III. *Sterility*. A case of male sterility was noted in a purple-pigmented plant. The emerging anthers instead of being purple were seen to be yellow and shrivelled up later without dehiscing. The anther sacs were devoid of free, healthy, pollen. This character was found to behave as a monogenic recessive to the normal condition.

IV. *Striped plant* (Plate I, Fig. 2). A single case of albino-striping was met with. This plant produced 31 tillers. The first was half albino and half green. The next six were all green and 4 white. Then again were formed seven green and the rest 10 white. Three tillers developing from the first were found to be green, though the parental one was half green and half albino. This is probably due to a chimaera, the mutation having taken place very early, probably even in the seed itself and affecting one half of the embryonal growing point, so that about half of the tillers is striped or white and the other half is green.

Seeds were collected from 27 tillers individually and progenies raised. The seed-setting in the heads from the green tillers was better (average 293 grains per head) than in those from the white ones (average 159 grains per head). The viability of the seeds was good (88% germination in seeds from green and 84% from those of white tillers). The progeny in either case (i. e., from the heads from green portion and that from white portion) gave green and pale seedlings. The proportions of green to pale seedlings were widely different :—

		Green	Pale	Ratio
i. Progeny from green tillers				
Total of 7 tillers	...	1074	350	3:1
,, 3 ,,	...	511	57	15:1 (approx)
,, 1 ,,	...	144	102	9:7
,, 3 ,,	...	254	327	7:9
ii. Progeny from white tillers				
Total of 4 tillers	...	414	168	3:1
,, 5 ,,	...	658	46	15:1
,, 1 ,,	...	58	50	9:7
,, 2 ,,	...	95	119	7:9
iii. Progeny from the half green and half white tiller	...	103	206	1:3 (approx)

On the total the progenies of this plant gave 3311 green seedlings and 1425 pale seedlings. Some of the pale seedlings that were allowed to

grow further put forth only green leaves. Neither the green nor the pale seedlings produced tillers with striping or albino.

Cytology:—Hector (1936) gives the following resume. "The chromosome number was first reported as ca. 48 (2n). According to Church (1929) the haploid number is 21. Avdulov (1931) found 54 (2n). Hunter (1934) 36. As the basic number of the Paniceae is 9, Avdulov's and Hunter's figures would appear to indicate polyploidy."

Echinochloa colona, Link. is a close relation of this plant which is cultivated as a millet in several parts of India and occurs wild all over the country.

E. colona appears to hybridize spontaneously with *E. colona*, var. *frumentacea*. The two plants can be distinguished easily by means of their panicle characters:

	E. colona	var. *frumentacea*
Rachis	Flat, triquetrous	Tetraquetrous
Arrangement of spikes	Bilateral, alternating	Whorled to spiral
Disposition of the spikes	Almost vertical and adpressed to rachis	Horizontal to ascending, divergent
Spikelets	Solitary or in twos, pedicelled	Always in groups of 3–5, sub-sessile.

The *colona* species itself sometimes shows a tendency to whorling. The weaker and later-formed panicles of *frumentacea* tend to be less whorled. The progenies of some natural hybrids gave in the F_2 a large number of intermediates with regard to the number of spikes and also the manner of arrangement.

Summary. *Echinochloa colona* var. *frumentacea*, originally classified under Paniceae (*Panicum crusgalli* var. *frumentaceum*), though one of the less important millets of India forms a good famine time fodder and grain plant.

It can be fed green or as hay, or as silage. The plant has the advantage that it can grow in poor soils, as also under water-logged conditions.

Three pigmentation types P. 3, P. 2, P. 1 and one non-pigmented type GT. have been described. These show a two factor difference.

The panicle-shapes are of three types—Open, semi-compact, and compact. These are considered to be due to differences in the length of spikes and density of the spikelets. The relationships of these three types are yet not fully clear.

A type of male-sterility, simple recessive to the normal condition has been described. Albino-striping was met with and its progeny has given seedlings with green and pale colours in various proportions.

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therefore highly cleistogamous which explains the complete absence of natural crossing in it. Any artificial manipulation of the spikelet irretrievably damages it and many attempts at emasculation and artificial pollination proved futile.

Grain. The grain matures in 30–35 days after flowering. It is tightly enclosed by the hardened fourth glume and its palea. The husk is coloured shades of brown. In the two seriate varieties, the grain is bigger and nearly twice the size of those in the non-seriate ones. In the variety imported from Sierra Leone (referred to above), though the head is two-seriate, the grain is small. The degree of emergence of the heads has no effect on the setting of the seed, both having about the same degree of sterility. In this millet seed-setting is dependent on the season. In the year 1928, the drought affected the seed-setting in some varieties to such an extent that not even a few grains per plant could be obtained. Under favourable conditions good yields can be expected.

False Polyembryony. In the year 1931, in the course of a number of seed germinations for albinism in this millet, two instances of two seedlings arising from a single seed were noticed. The seedling had a single root and two plumules each with its own coleoptile. At the surface of the seed, the two were separate. Paraffin sections of the seed showed that the plumules had independent vascular bundles. Lower down, the cortical portions of the two shoots were found to unite, the bundles running separate. In a few sections lower down, the vascular bundles were closer and approached each other until finally they became enclosed in a single endodermis. Sections still lower down showed the root strand run into this single bundle. From this examination of the course of the vascular bundles and also of the cortical region, it will be seen that what appears to be independent at the top is, in reality, the result of the branching of a single seedling. At a very early stage in the development, the mesocotyl has branched into two, resulting in the double seedling—a case of false polyembryony. Cases of pseudo-polyembryony have been recorded by other workers. Only those pertaining to the Gramineae are noticed. In maize, Kiesselbach (1926) noted seedlings with (1) two plumules each with its own coleoptile and two primary roots enclosed in a single coleorhiza, (2) a single plumule with two primary roots in a single coleorhiza. In the case reported here, there are two plumules each with its own coleoptile but with a single radicle.

Paspalum Sanguinale, Lamk. Several species of Paspalum, especially *P. dilatatum* are grown in America, Australia and South Africa as pasture grass. A wild ally of Paspalum known as *Chicco* (*P. sanguinale*, Lamk) is grown in the Vizagapatam District. This was grown at the Millets Breeding Station for a number of years and the following notes are appended.

flowering begins between 2-30 and 3-0 a. m. on each day and continues till sunrise. Youngman and Roy (1923) note that these flowers open between 7-30 and 8-0 a. m. at Nagpur. Flowers do not commence to open from any definite region. They usually start from the middle of the floral branch and gradually spread to either ends. Instances in which flowers begin to open at either end are met with occasionally.

Anthesis of a Flower (*anthers extruded*). Detailed observations on the anthesis in a normal average flower are recorded below showing the trend of sequence.

2-30 a. m. Glumes begin to open.
2-40 ,, Anthers visible through opening.
3-15 ,, Anthers emerge.
3-30 ,, Anthers completely out.
3-35 ,, Anthers dehisce.
3-45 ,, Glumes close completely.

The stigmas may or may not come out of the glumes. When the glumes begin to gape the anthers crowd at the orifice and are undehisced. They are mostly non-emergent. Their filaments are 1 mm. in length. In stray cases anthers emerge, their filaments being 6 mm. long. These filaments remain turgid for a long time, often till 8-9 a. m. The anthers may emerge simultaneously or one by one or two at a time followed by the third. This stray emergence accounts for the paucity of evidences of flowering in this unobtrusive millet. When the anthers remain inside the flower, their dehiscence takes place long after the opening of the glumes. Dehiscence starts as a slit at one end and gradually spreads or it begins in the middle and proceeds to the ends. The stigmatic feathers dry in the evening. The anthers remain fresh and do not wither till next morning. The lodicules are fleshy and do not shrink immediately after the anthesis of flowers but remain fleshy for 6—8 hours after the opening of the glumes and then dry up—a probable device preventing the closing glumes from jamming the anthers.

Progress of Flowering. The following table connotes the daily anthesis energy of the 15 per cent of flowers opening during the flowering period, emerging and non-emerging anthers included.

Day of Flowering.	2-3 a. m.	3-4 a. m.	4-5 a. m.	5-6 a. m.	Total.
First Day	14	1	1	–	16
Second Day	2	10	–	1	13
Third Day	7	11	–	–	18
Total.	23	22	1	1	47

N. B. 15 per cent of the flowers in the head opened. The remaining 85 per cent were cleistogamous.

It will be seen that all the flowers in the head do not open. The percentage of open flowers in the varieties varies from nil to 50 per cent., the most frequent being 10 to 15 per cent. This millet is

The seed which is very small takes 7 days to germinate, two days later than for *Varagu*. Unlike *P. scrobiculatum*, the seedlings are green and have no purple pigment anywhere in the plant. Before flowering the plants are spreading and almost prostrate. The panicle-bearing tillers become erect at flowering. Unlike *Varagu* the internodes are hollow and much exposed. At ripening stage they have a golden yellow colour. The nodes are glabrous and not swollen. The flag is the broadest leaf in the plant. The upper surface of leaves is rough and the lower is smooth. The leaves are arched and not bent. The plants have five to six heads with long well emerged straight peduncles. Occasionally their fullness leads to goose-necking. The panicle has a general resemblance to that of a well grown *Chloris barbata*. It consists of a number of fingers (or branches) arranged in irregular whorls along a short axis. An average earhead may have about 40 fingers. The bulk of these arise from the two bottom whorls, the rest of them being distributed to those above, mostly in twos and threes. Each finger may have about 100 flowers. The spikelets are arranged alternately in clusters of one to three. The spikelets are very small, the length in each being four to five times the width. The glumes are prominently ribbed and dry to a straw colour. The structure of the spikelet is like any other Paspalum. The flowers of this wild ally open from 1—30 a. m. and the anthesis continues up to 7 a. m. The greatest anthesis energy is within the first hour after opening. It takes four to five days for a panicle to complete its flowering.

This wild Paspalum scores over *P. Scrobiculatum* in a number of points, viz., more herbage, free earheads, greater drought resistance, larger number of seeds per head and absence of sterility. A cross with this wild ally is indicated as a potential source of improving the Kodo millet, if the difficulties in the manipulation of this close and delicate cleistogamous flower could be overcome.

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Samai—The Little Millet—*Panicum miliare*, Lamk.

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Origin. Very little literature is available regarding the place of origin of *Samai*. De Candolle (1884) does not make any reference to this crop in his "Origin of Cultivated Plants". According to Blatter and McCann (1935) "the crop is cultivated or naturalised throughout India and Ceylon; cultivated in the Tropics". Chevalier (1922) mentions that this species is cultivated only in British India and Ceylon, and perhaps also in Central China.

The fact that it has a name in almost all languages of India, and that its wild ancestor *P. psilopodium* is found abundantly in India, Burma and the Malay Peninsula, indicates that *Samai* was first brought into cultivation in India.

Distribution. *Samai* is grown to a limited extent in almost all the provinces of India. Its cultivation extends upto an elevation of 7,000 feet or more. It is found wild (probably escaped from cultivation) in the Punjab, Burma and South-Eastern Asia. It has very little importance outside India except probably in Ceylon where it is cultivated to a small extent. It has been tried, though not with much success, in the Straits Settlements and the Federated States of Malaya. The crop has also been tried on an experimental basis in many parts of Africa by the European settlers; but its cultivation there is unimportant (Sampson, 1936).

Botanical description. The description of *Samai* has been given by Hooker (1875), Gamble (1934), and Blatter and McCann (1935). Brief descriptions are also found in many books dealing with grasses. A comprehensive description based on the above authors is given below.

Panicum miliare, Lamk., belongs to the tribe *Paniceae* under Gramineae. Its specific name, *miliare*, is derived from the old latin *milium* meaning millet. An annual grass, with culms 30—90 cm. high, rather slender, erect or base geniculate, simple or branched; *leaves* linear 15 to 50 cm. or more in length, 12 to 25 mm. broad, gradually tapering from a broad base, glabrous or finely hairy; *Sheath*—rarely hairy with tubercled—based hairs; *Ligule*—a narrow row of hairs; *Node*—glabrous; *Panicle*—very compound, contracted or thyrsiform, often nodding, 15 to 45 cm. long; *Spikelet*—glabrous, rather flattened, suddenly cuspidate, 3—4·5 mm. long, mostly paired on unequal pedicels, but often solitary at the end of the branchlets, lanceolate in flower, elliptic or broadly elliptic in fruit. *Glums I.* Very broadly ovate, subtruncate, then suddenly acute, or scarcely acute, about

* Paper read before the meeting of the Association of Economic Biologists, Coimbatore on December 20, 1940.

1/3 the spikelet, white, membranous, 3—5 nerved, nerves arching and anastomosing. *Glume II.* Herbaceous ovate lanceolate, 11—13 nerved, almost as long as the spikelet. *Glume III.* Herbaceous, broadly ovate, 9 nerved, slightly shorter than *Glume II*, palea as long as the Glume (3—4 mm.), flower neuter or rarely with 3 stamens. *Glume IV.* Narrow elliptic, or elliptic-oblong to broadly ovate, acute, shining white or pale brown or dark brown, often 3—5 streaked dorsally; *Fruit* Caryopsis enclosed tightly within the fourth glume and its palea (2·5 to 3·5 mm.).

Note Some of the samples of *Samai* collected from the Agency tracts of Ganjam and Vizagapatam are much taller (100—150 cm.) and later (120—140 days) than the types from other parts of the Presidency. These do not tiller so profusely as the short duration varieties, there being only 3—5 tillers, with each tiller bearing a good-sized head. The culm is stout, about 10—15 mm. in diameter and the leaves are proportionately large. The varieties maturing in 70—90 days are shorter in height, (30—70 cm.), tillering profusely, (upto 25 tillers), especially under irrigation. Secondary branching is quite common in these varieties. The main axis of the panicle is nodding especially after the grain has set.

Agricultural varieties. Names of agricultural varieties are usually descriptive of duration, grain and plant pigmentation, and panicle shape. It is of common knowledge that the wealth of varieties and varietal names show the antiquity and the importance of a crop in the locality. Basu (1890) mentions five varieties cultivated in Bengal (1) The Black or *Kariya*, most commonly cultivated (2) The white or *Charka* (3) The ant-headed *Dia-muri* of a motley colour (4) The *Burhi*, a late variety and (5) the *Bere*, a variety always grown mixed with ragi. In the Madras Presidency most of the samples collected have no special names except the general term *Samai*. However, a few had varietal names which are listed below with the characteristics of the samples.

Name and place of collection.	Duration in days.	Pigmentation.	Panicle.	Grain colour
Ajjamu, Kamakarai, Kollegal.	133	Mixture of P. and medium P.	Loose	Olive Brown (O Br.)
Aruppu Samai, Ramnad.	88	Mixture of P. and medium P.	Loose	Light olive brown (L O Br.)
Bele Samai, Mundigundum, Kollegal.	133	Medium P.	Branched and normal heads, half open panicles	Mixture of very light olive brown (VLOBr) and LOBr.
Chittan Samai, Reddiyur, Javadi Hills.	87	Mixture of P. and medium P.	Loose	LOBr.
Jupy Suwa, Monliguda, Jeypore.	108	Mixture of P. and G. T.	One-sided	Mixture of VLOBr. and LOBr.
Karboka Samai, Ambrampalayam, Pollachi.	81	Mixture of P. and medium P.	Compact	Mixture of LOBr. and OBr.

Kar Samai, *Okkilipalayam*, Pollachi.	83	Mixture of P. and medium P.	Compact	Mixture of LOBr. and OBr.
Kollu Samai, Kumblankolam, Palur.	102	Medium P.	Loose	Mixture of VLOBr. LOBr. and OBr.
Malligai Samai, *Manapparai*.	132	Medium P.	Loose	LOBr.
Pedda Samalu, Parvathipuram, Vizagapatam.	132	Mixture of P. and medium P. and G. T.	Mixture of dropping and erect panicles	Mixture of VLOBr. and LOBr.
Perum samai, Ramnad.	135	Medium P.	One-sided	LOBr.
Perum Samai, Kumblankolam, Palur.	106	Medium P.	One-sided	Mixture of VLOBr., LOBr. and OBr.
Porukku Samai, Ramnad.	135	Medium P.	One-sided	LOBr.
Punam Samai, Taliparamba.	127	Mixture of P. and G. T.	Arched	Mixture of VLOBr. & LOBr.
Sada Samai, Manapparai.	132	Medium P.	Branch and half open	LOBr.
Vellai Samai, Punganur.	87	Mixture of P. and Medium P.	Loose	LOBr.

Extent of cropping. Figures are not available to know the exact acreage of this crop in India. In the Madras Presidency the normal area under this crop is 589,940 acres. About 21% of this area is in Salem, 18% in Anantapur, 13% in each of Coimbatore and Madura, 8% in Tinnevelly and 6% in North Arcot. The districts of Trichinopoly, Vizagapatam, Chittoor, Bellary, Ramnad and Malabar grow this crop to a certain extent, but the area is below 5%. The crop is unimportant in the other districts.

The Role of Samai in the system of cropping. The importance of *Samai* as a crop is neither in the total area cultivated nor in the money return it gives to the cultivator, but that it gives something in the shape of food-grain to the ryot, from a soil which may otherwise yield little or nothing. It is a hardy crop which can withstand drought better than most of the other cereal crops and also water-logging to a certain degree. If the crop fails, the cultivator stands to lose very little, for the cost of production is very small and the assessment of the land very low.

Cultivation of Samai. Season. With the receipt of the sowing rains, the *ryot* attends first to the more valuable crops and then only to *Samai*. Naturally he reserves his best lands to his more profitable crops and

sows *Samai* in the poorer ones. Often it forms one of the mixtures and as such its sowing coincides with other dry land crops. It may be said that the sowing season of *Samai* is determined according to the advent of the South-West monsoon rains, i. e., June—July or August in the districts of Malabar, Coimbatore, Salem and Anantapur, the Agency tracts and in parts of Madura, Ramnad and Trichinopoly districts. In parts of Coimbatore and Tinnevelly districts it may also be sown in August—September. Rarely it is grown in April with the hot weather rains.

Rotations. The scope for rotations is very limited because of the nature of the soil on which it is sown. In single-crop dry lands of an inferior type as in the central division of Anantapur district, *Samai* follows horsegram in a two-year rotation. In parts of Salem, which are favoured by both the monsoons, *Samai* is sown in the South-West monsoon season and is followed by horsegram in the North-East monsoon. In parts of Tinnevelly near the Western Ghats, it is grown as a second crop in October—November after a cholam crop. In the uplands of Malabar and in Bengal, *Samai* follows dry land paddy or blackgram. In Bombay it follows *ragi* in dry lands. What is lacking by way of rotations is made up by mixed cropping. The usual crops grown as mixtures are *Samai, cumbu,* and *varagu,* among the cereals, lablab, horsegram and blackgram as pulses and occasionally mustard, gingelly and castor also.

Cultivation. *Samai* is cultivated only as a rainfed crop. It is seldom raised on garden lands, chiefly because better crops are selected for such lands and the increase in the outturn of *Samai* would very seldom pay for the cost of irrigation. With the advent of rains, the land is broken up with an ordinary plough. Two or three ploughings are usually given. Very little manure is applied, the available manure being used up for more paying crops. The seed is sown broadcast at the rate of about 10 lb. per acre, (when sown pure) and covered by ploughing once or twice. The field is sometimes levelled with a brush harrow or a levelling board. One weeding is usually given and nothing more is done until harvest time. This method of cultivation is common in almost all parts of India, the only exception being that the crop is sometimes transplanted in parts of Bombay. A special kind of cultivation of this millet, "the shifting cultivation" is prevalent in many hilly parts of India especially in Madras, Bombay, Bengal and Central India.

Harvest. The crop is cut close to the ground, tied up into sheaves and allowed to dry. When fully dry, it is threshed out by cattle if there is a sufficient quantity, or simply trodden down by foot. When cultivated on the hills, the crop is cut half-way leaving a stubble of $1\frac{1}{2}$ to 2 ft. in length, which is subsequently burnt to form manure for the next crop.

Duration. *Samai* takes usually $3\frac{1}{2}$ to 4 months to mature. There are varieties which mature in $2\frac{1}{2}$ to 3 months. Some of the hill varieties from the Agency tracts take about five months to mature.

Yield. The yield varies from 200 to 500 lb. of grain and 800 to 900 lb. of straw (semi dry).

Grain. The grain is husked before cooking. The husk forms about a third of the grain. The husked grain is cooked like rice and eaten. In parts of Tinnevelly and Malabar the grain is boiled before husking, similar to the parboiling of paddy. The rice is sometimes ground into flour and cakes are made out of it. As a food, *Samai* rice is not very tasty and is seldom preferred to any other grain if available. According to Church (1886) the analysis of *Samai* grain is as shown below:—

Water	10·2
Albuminoid	9·1
Starch	69·1
Oil	3·6
Fibre	4·6
Ash	3·5

The nutritive ratio is 1: 8·4 and the nutrient value of 85.

Straw. The cattle are fond of the straw, but in South India as a fodder it is considered inferior to that of paddy and *ragi* straw. In Northern and Central India, the straw has little value as fodder. It is cut and put into the manure heap or simply burnt down to form ash for the next crop.

Anthesis and Pollination. The only record available is that published by Youngman and Roy (1923). They have stated that the time between the opening and closing of the flower is 15 to 20 minutes only. At Nagpur, the flowers open between 9-30 and 10-30 A. M. With the commencement of the opening of the glumes, the styles and the filaments spring out at once, with explosive suddenness. Self-pollination is the rule in this crop.

Detailed studies were made at the Millets Breeding Station, Coimbatore on the anthesis and pollination in *Samai* in the year 1936.

Emergence of the Panicle. As in the case of *ragi*, (Ayyangar and Wariar 1934) the flag, the leaf subtending the panicle, cannot be differentiated from other leaves and hence the emergence of the panicle which is contained in the sheath of the flag has to be closely watched. From the emergence of the tip of the flag from the last leaf-sheath, it takes four to five days for the appearance of the inflorescence. In many cases the inflorescence does not emerge completely from the sheath of the flag; the lowermost branches remaining inside.

Order of anthesis. The opening of the flowers commences on the second or third day after the appearance of the panicle. The flowering progresses from the top to the bottom of the panicle. The maximum number of flowers opens on the 6th or 7th day. It takes about a fortnight to complete the flowering in a panicle. Observations were also made on the period of opening of flowers. It shows that in fair weather, the flowers begin to open by 9 or 9-30 A. M. The flowering progresses rapidly upto 10-30 or 11 A. M. after which it begins to decrease gradually and stops by 11-30 A. M. If the weather is cloudy the flowers may continue to open

upto 12 noon, but not afterwards. Differences in the season of sowing or methods of cultivation do not affect the order of anthesis, or the period of opening of flowers in a day.

Detailed observations were made on a number of individual flowers. The following table gives the average time required for each stage of the anthesis.

Details of anthesis.

	Average time taken	
	On a clear day.	On a cloudy day.
	min.	*min.*
Glume begins to gape	0	0
Stigma and anther visible (begin to emerge)	1	19
Anthers emerge (out of glume)	1½	19
Beginning of dehiscence	2	20
Completion of dehiscence	2	21
Stigma separate and become divergent	2	21
Glumes begin to close	3½	21
Glumes close completely	5½	22
Stigma begins to wither	6½	22
Stigma withers completely	19	28

The first sign of the opening of the flower is seen when the third glume slightly separates from the fourth glume. The palea then begins to separate itself gradually from the fourth glume. The opening of the flower is brought about partly by a swelling of the lodicules and partly by pushing from inside by the growing anthers. In fair weather, the opening of the flower is a quick process and is accomplished in one to three minutes. If the weather is cloudy the opening may take up to 20 minutes, the rest of the process being similar.

Within a minute of the gaping of the glume, the filament of the anthers elongate and by the time the glume is completely open, the three anthers as a column reach the mouth of the gaping glume with the stigmatic branches protruding from its periphery. The dehiscence of the anther takes place at the mouth of the glume or just before the anther reaches that position. The free pollen gets dusted on to the stigma. The filament then elongates and the anthers become pendant. As a result of this elongation of the filaments and spreading out of the anthers, the stylar arms that were caught up within these filaments are able to diverge and take up a position on either edge of the glume, exposing the two stigmas. The whole process of anthesis is fairly rapid and is completed in two or three minutes. Immediately after the anthers assume their pendant form, the glume begins to close. This closing is completed in about two minutes leaving the anthers and the stigma outside. A glume once closed never reopens. From the foregoing account it would be clear that self-pollination is the rule in this millet. The percentage of natural crosses occurring in *Somai* is very low (about 0'05).

Artificial Hybridisation. The artificial emasculation and pollination of this millet is rather a difficult process. However, the glumes can be opened and anthers removed with a fine-pointed forceps. The desired pollen can then be dusted on to the stigma. Such operated flowers are enclosed in a glass tube in order to exclude foreign pollen. The percentage of success depends mainly on the dexterity of the operator. An easier method of hybridisation is "the contact method" of crossing which is described in detail in connection with the anthesis and pollination in *ragi* (Ayyangar, and Wariar, l. c). The percentage of F_1s obtained by this method ranges up to 5.

Inheritance of Characters. Anthocyanin Pigmentation. Two broad groups may be distinguished in *Samai*, one with purple pigmentation and the other without it, the "Green-throughouts". Among the purple-pigmented plants, two types are distinguishable and are designated, Purple and Medium purple. The characteristics of three types of pigmentation are given below.

Purple (*P*). In this type the pigmentation is manifested on the leaf, the leaf-sheath, the exposed internodes, the glumes and the stigma. The anthers are orange in colour. It is interesting to note that the node and the junction of the leaf are not coloured in any of the pigmented types.

Medium Purple *(Med. P.)* This type has the leaf, the leaf-sheath, the exposed internodes and the stigma coloured purple. The glumes are green and the anthers orange.

Green Throughout *(G. T.)* The plant is free from purple pigmentation on any of its parts. The anther is orange and the stigma colourless.

Crosses were made for elucidating the inter-relationship of these types of pigmentation. A cross between P. M. 21 (G. T.) and P. M. 31 (P.), gave the F_1 as Purple. In the F_2 it segregated into 53 P. and 18 G. T. indicating a 3:1 ratio. Another cross between P. M. 33, (G. T.) and P. M. 27, (Medium P.), gave a Medium Purple F_1 and segregated for 56 Med. P. and 16 G. T. in the F_2 indicating a 3:1. A third cross between P. M. 27, (Med. P.) and P. M. 30 (P.), gave a Purple F_1 and segregated into 103 P. and 34 Med. P., showing a 3:1 ratio. Crosses were made between P. M. 33, (G. T.) and P. M. 31, (P.) which gave Purple in the F_1 and 64 Purple, 23 Med. P., and 27 G. T. in the F_2. Its behaviour is given below:—

Generation No.	Family No.	Behaviour		
		P.	Med. P.	G. T.
	Parents	P. M. 31		P. M. 33
F_1	Cross P. M. XII and XIII	F_1		
F_2	P. M. 133 and 134	64	23	27
	X^2 = ·33 P between 8 and ·9.			
F_3	1 family	89		
(From P.M. 133)	2 families	141	44	
	3 families	90		31
	5 families	142	45	58
	3 families		176	
	3 families		111	38
	2 families			72

A Factor P is responsible for the production of Purple pigmentation on the body of the plant and stigma of the flower, thus giving a Medium purple plant. P is a simple dominant to p the Green-throughouts. A factor H colours the glume purple thus producing a Purple plant. H is a simple dominant to h. The effect of H is noticeable only in the presence of P. The interplay of these two factors P and H thus results in a 9 : 3 : 4 ratio of P. (PP HH) : Med. P. (PP hh) : G. T. (pp HH or pphh). The behaviour is parallel to the one observed in *Eleusine coracana* (Ayyangar *et al*, 1933).

Grain Colour. Grain colour in *Samai* can be grouped into three types viz., very light olive-brown or the white grain ; Light olive-brown and olive-brown, popularly known as *Karum Samai* or *Nalla Samalu* in Madras and as *Kariya* in Bengal. The inter-relationship of these three types has been worked out and is presented below.

A natural cross, P. M. 167, having a very light olive-brown grain was spotted in P. M. 21, a Light olive-brown grained type. In the F_2, it segregated into 98 Very light olive-brown and 29 Light olive-brown grains, indicating a monogenic segregation. Another family, P. M. 60 (Light olive-brown grain) segregated for 103 Light olive-brown and 41 Olive-brown grains showing a 3 : 1 ratio. Having observed these monogenic differences between successive groups, crosses were made between P. M. 33, Very light olive-brown and P. M. 20, Olive-brown type. The F_1 had Very light olive-brown grain. In the F_2 there were 22 Very light olive-brown, 18 Light olive-brown and 2 Olive-brown grained plants, a ratio suggesting a 9 : 6 : 1. The F_3 behaviour given in the accompanying table confirms the ratio obtained in the F_2.

Generation No.	Family No.	Behaviour		
		Very light olive-brown	Light olive-brown	Olive-brown
	Parents	P. M. 20		P. M. 33
F_1	Cross P. M. XIX	F_1		
F_2	P. M. 136	22	18	2
	X^2 = ·55 P between ·7 and ·8			
F_3	2 families	190		
	6 families	277	89	
	4 families	166	108	17
	5 families		484	147
	3 families		353	
	2 families			187

Two additive factors I_1 and I_2 act as inhibitors on the olive-brown grain (X), the colour base. When any one of these factors is present, the colour of the grain is Light Olive-brown and when both are present, the grain becomes Very light olive-brown or white, thus giving a factorial composition of i_1i_2X for Olive Brown, i_1I_2X or I_1i_2X for Light olive-brown and I_1I_2X for Very light olive-brown grain. These factors have no relation with the plant purple pigmentation groups.

Albinism. One family P. M. 217, when sown was found to segregate for green and albino seedlings. Counts taken from P. M 217 gave 1044 green seedlings and 72 albino seedlings showing a 15:1 ratio of green to albino. From the surviving greens fortyfive single plants were carried to the F_3 generation Of these nineteen were pure for green seedlings fourteen segregated for green and albino as 3:1, while twelve gave 15:1 ratio of green to albino.

Generation No.	Family No.	Behaviour		
		Green	Albino	
F_2	P. M. 217	1044	72	$X^2 = 06$
F_3	19 Families (pure)	1637		P> 8
P. M. 217	14 Families (3 : 1)	1315	421	
(1--45)	12 Families (15 : 1)	1590	109	

As in the case of *Eleusine coracana* (Ayyangar and Krishna Rao, 1931) two factors C_1 and C_2 are responsible either alone or together for the production of chlorophyll in *Samai* also. In the absence of both of these factors, the plant is an albino and dies off in about ten days.

Pests and Diseases. There is no record to show that this crop is subject to the attack of any serious insect pest *Samai* (Butler 1918) is subjected to the attack of a fungus known as *Uromyces linearis*, B. and Br. The fungus is known only in India, Ceylon and the Phillippine islands and no information is available as to the extent of the damage which it causes. It is a rust affecting the leaves of the plant.

Summary. This paper presents a brief account of a minor millet, *Samai—Panicum miliare*, Lamk.

Studies on anthesis and pollination have shown that the flowers open between 9 A. M and 12 noon under Coimbatore conditions and that self-pollination is the rule. Emasculation and artificial pollination can be done with a fair amount of success. Very good results can also be obtained by "contact crosses".

Two types of purple pigmented plants, Purple (PH) and Medium purple (Ph) are met with, while with p, the plant is green-throughout. A segregation where these three groups occur has given a 9:3:4 ratio of P, Med. P and G. T.

Three types of grain colour viz., Very light olive-Brown, Light olive-brown and Olive-brown occur in *Samai* by the interaction of two additive factors I_1 and I_2, inhibitory in effect on Olive-brown grain.

Albinism was noted in the seedlings of *Samai*. Duplicate factors C_1 and C_2 are responsible for the production of chlorophyll either alone or together.

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